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Rig Math

The Calculator and Main Keyboard

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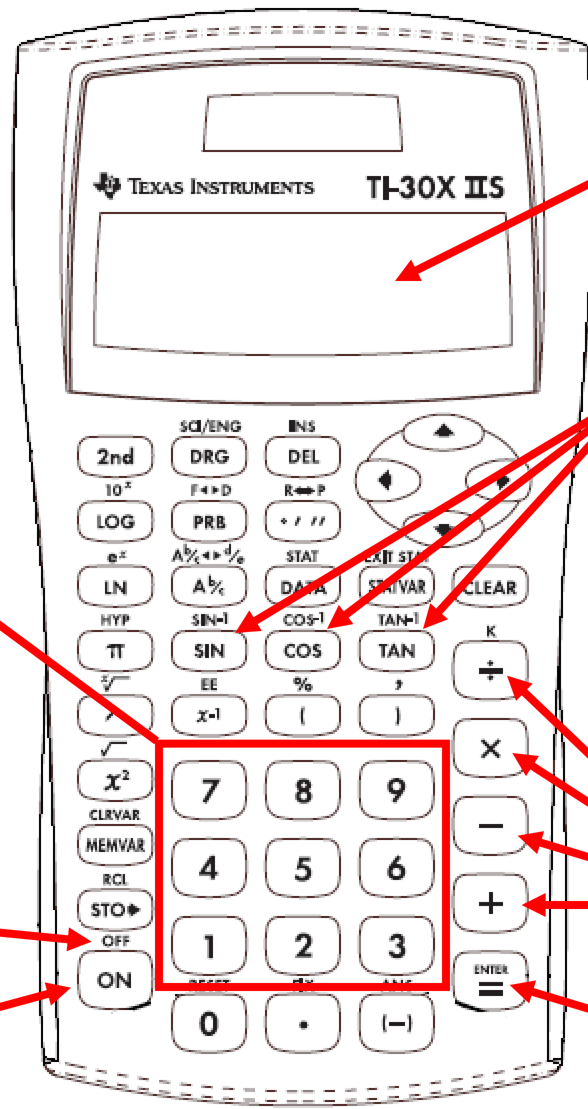
Numerical 10-key pad – used for entering numerical values

These are the keys that will be used for basic calculations

Power Off Switch

Power On Switch



Display

Trigonometric Functions

These keys will be used where wellbore angle is an issue

Basic Math Operations

Equal Key

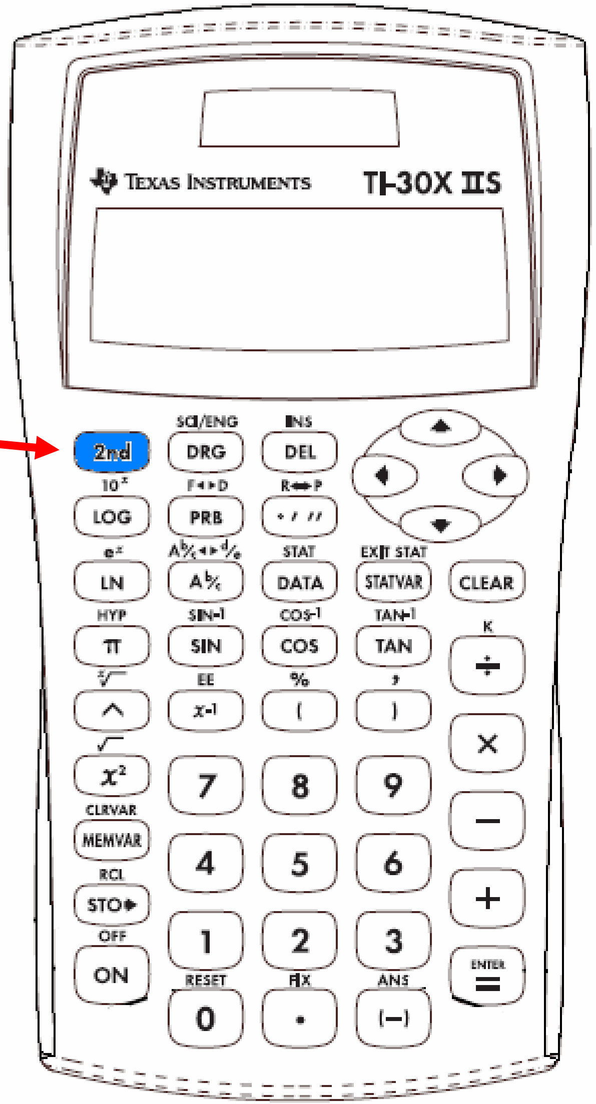
Resolves operations

Courtesy of Texas Instruments

The 2nd Keyboard and Accessing the 2nd Keyboard

The **2nd** keyboard is turned by pressing the **2nd** key. All **2nd** keyboard functions are in blue an are located above the keys of the main keyboard.

2nd Key



Your instructor will guide you in using the second keyboard and related functions as they are needed.

Courtesy of Texas Instruments

"Fixing" The Display

Fixing the display means to tell the calculator how many decimal points are to be displayed with each calculation. The factory default setting for the calculator is to display calculations in 9 decimal points. Not only is this a bit cumbersome to read but is also not practical for the calculations to be done in this course.

How To Assign The Number of Decimal Points

To fix the display the 2nd keyboard must be accessed. Press the **2nd** key to turn on the 2nd keyboard. Just above the decimal point you'll see the word **FIX**. Press this key.

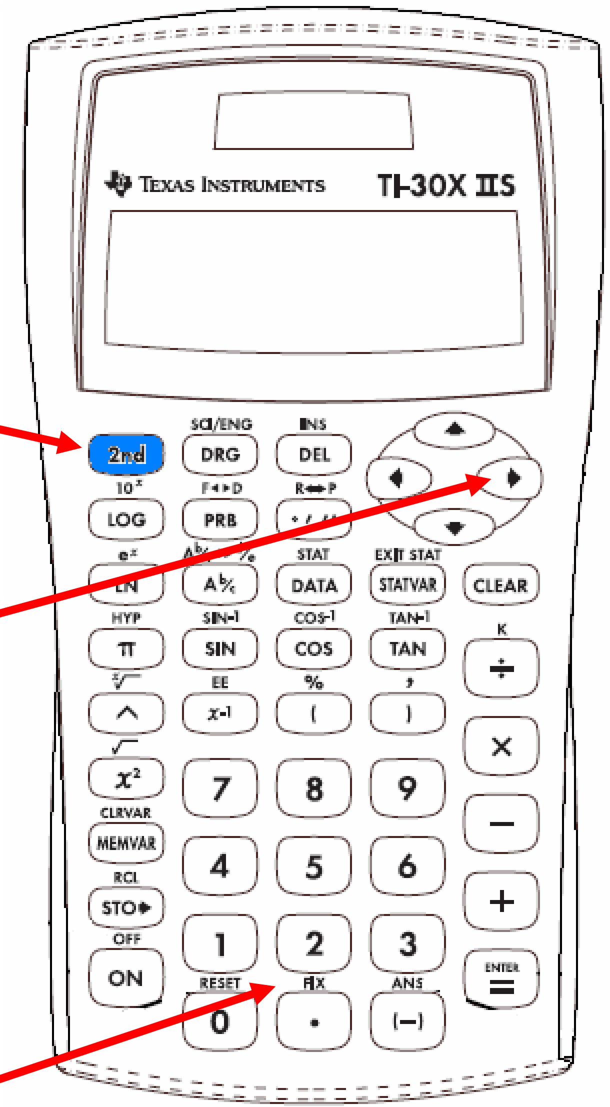
At right is the display after selecting **FIX**.

Use the **RIGHT ARROW KEY** ►

Pres this key to select the number of decimal points you want to appear in the display.

Once you have the cursor under your selection press the **ENTER** key. The calculator then leaves the 2nd keyboard and returns to the main keyboard.

2nd Key



FIX

Courtesy of Texas Instruments

Addition

#1 88 + 109 = **197**

#2 1189.96 + 23.87 = **1,213.83**

#3 252311 + 19855 = **272,166**

#4 23.674 + 11000032 = **11000055.674**

The addition key **+** is used between the two numbers that are to be added. Follow this with the **ENTER** **=** key.

You'll notice that the numbers you entered along with the answer appear in the display.

Subtraction

#1 188 – 139.87 = **48.13**

#2 553833 – 358127 = **195,706**

#3 .8786 – .5491 = **.3295**

#4 38.33 – 35.8127 = **2.5173**

The subtraction key **–** is used between the two numbers that are to be subtracted. Followed by the **ENTER** **=** key.

You'll notice that the numbers you entered along with the answer appear in the display.

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Multiplication

#1 $55 \times 3.5 =$ **192.5**

#2 $553833 \times .8 =$ **443,066.4**

#3 $.8865 \times 78.81 =$ **69.8651**

#4 $42 \times 1.35 =$ **56.7**

Division

#1 $5.543 \div 3.82 =$ **1.451**

#2 $\frac{24.87}{16.19} =$ **1.5361**

#3 $\frac{553.875}{.9855} =$ **562.0244**

#4 $\frac{2.375}{2.5} =$ **.95**

The multiplication key **X** is used between the two numbers that are to be added. Followed by the **ENTER** key.

You'll notice that the numbers you entered along with the answer appear in the display.

The division ÷ key is used between the two numbers that are to be divided. Follow this with the **ENTER** key.

You'll notice that the numbers you entered along with the answer appear in the display.

5.543/3.82

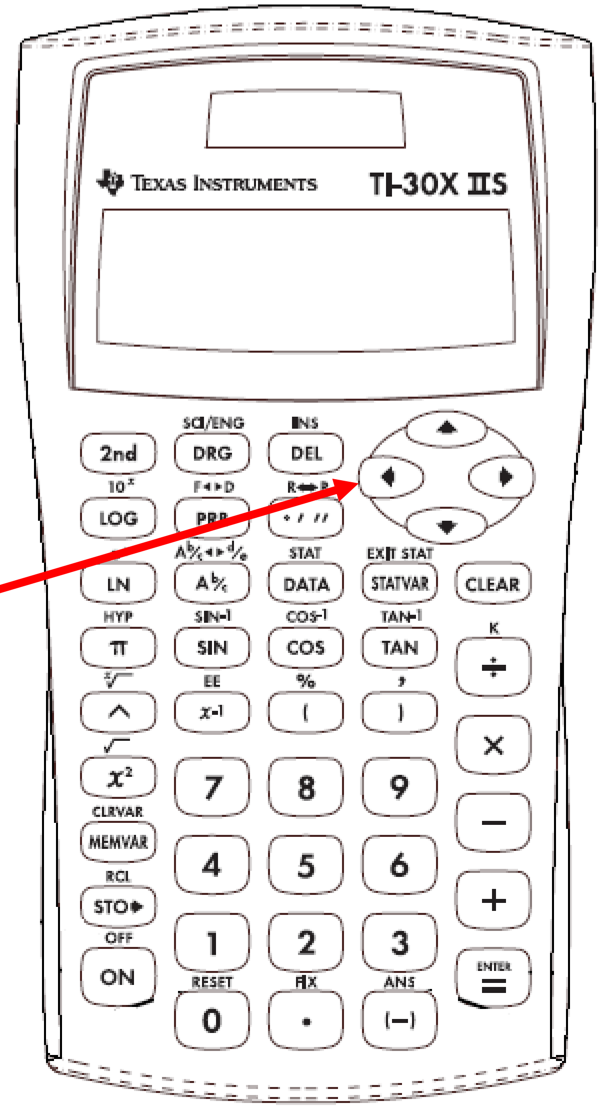
Division will appear this way in the display.

Correcting Entry Mistakes

If you enter a wrong number, it can be corrected without having to clear everything that's been entered, especially if you're working with a large formula or lengthy calculation.

For example: you want to enter the number 8.755 but instead you enter 8.577. This can be easily corrected by using the **Left Arrow** key.

Press the **LEFT ARROW** Key until the cursor is over the mistake. With the cursor in the correct place, simply reenter the correct number.



Courtesy of Texas Instruments

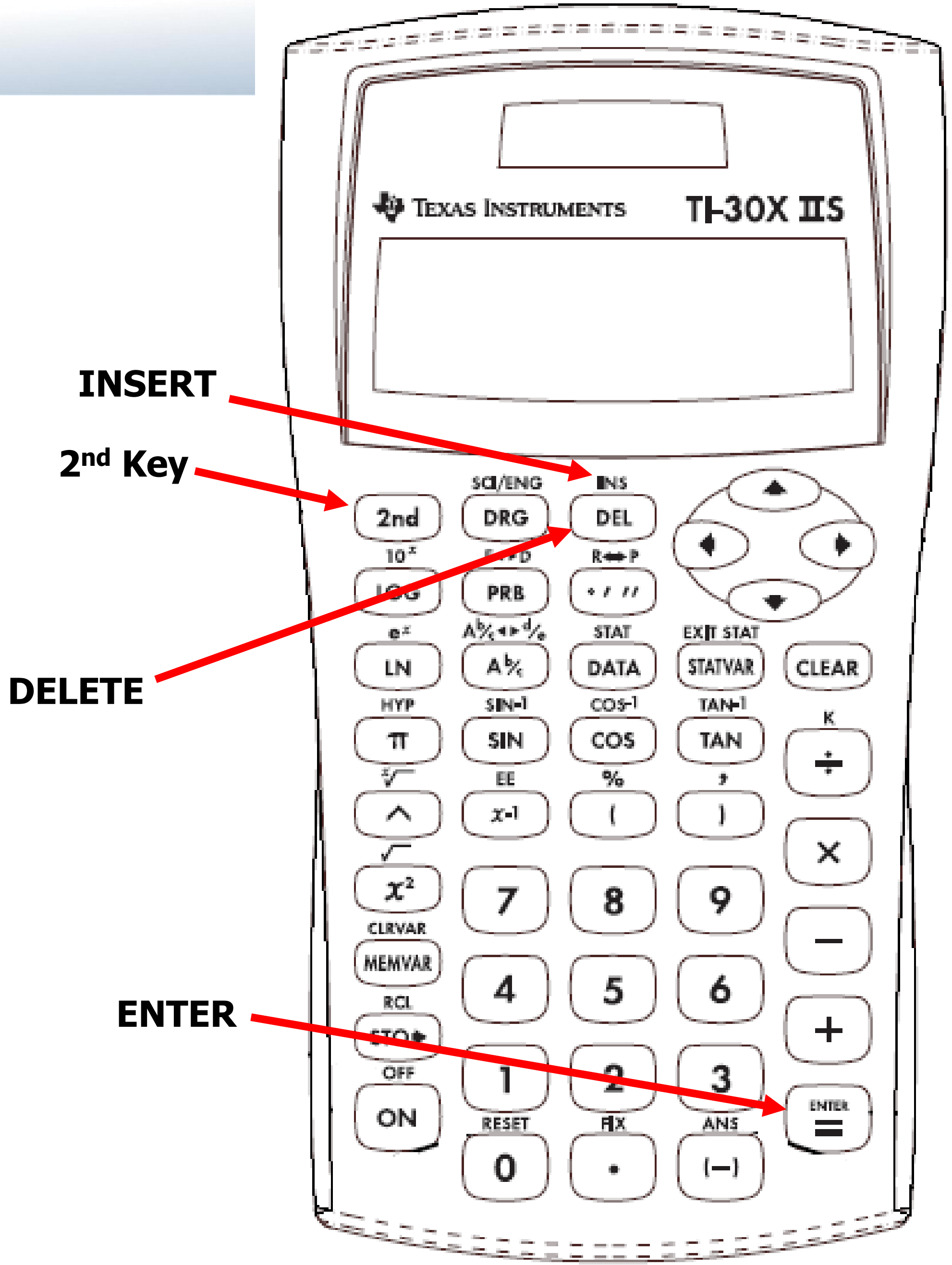
Correcting Entry Mistakes

Another means of correcting a mistake is to use the **DELETE** and **INSERT** keys.

Place the cursor over the mistake and press the **DELETE** key until the mistake is erased.

Then press the **2nd** key to activate the **INSERT** function, since this is on the **2nd** keyboard.

Insert the number you want to appear in the display and then press the **ENTER** key.



Courtesy of Texas Instruments

Converting Fractions to Decimals

$$\frac{1}{2}, \frac{3}{8}, \frac{5}{8}$$

These are all common fractions. And when these are encountered and are part of a calculation, they have to be converted to a decimal form. This is done by performing the operation they represent, which is ***division***. The top number, called the ***numerator*** is divided by the bottom number known as the ***denominator***.

$$\frac{1}{2} = \underline{\quad .5 \quad}$$

$$\frac{3}{8} = \underline{\quad .375 \quad}$$

$$\frac{5}{8} = \underline{\quad .625 \quad}$$

If the fraction is one that is used in conjunction with a whole number, then the fraction is converted to decimal form and added to the whole number.

For example: 9 5/8" casing is a common size. But there are cases where we have to know the OD in terms of decimal.

$$9\,{}^{5}\!/_{8}\ Csg$$

$$9 + \frac{5}{8} =$$

$$9.625 + .625 = 9.625$$

Another example:

$$2\,{}^{7}\!/_{8}"\ Tbg$$

$$2 + \frac{7}{8} =$$

$$2 + .875 = 2.875$$

Exponentiation - Squaring

X^2 …. or better known as squaring….

To square a number (multiplying the number by itself), enter the number and then press the **X^2**.

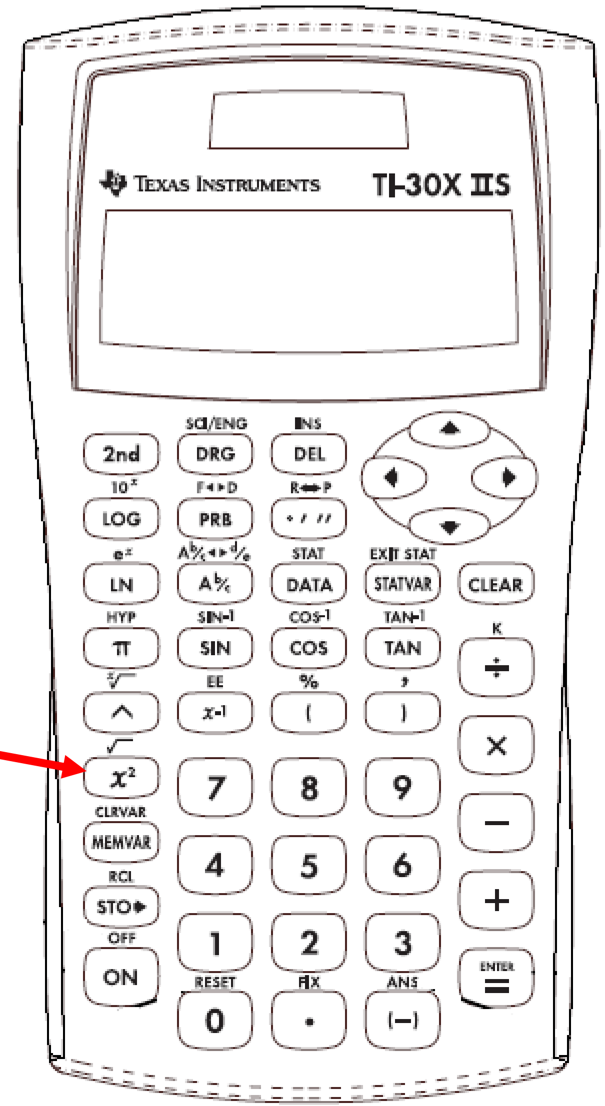
#1 $3.5^2 =$ **12.25**

#2 $12.25^2 =$ **150.0625**

#3 $4.5^2 =$ **20.25**

#4 $125.02^2 =$ **15,630.0004**

X^2



Courtesy of Texas Instruments

Exponentiation – Powers Greater Than 2

If a number is to be raised to a power greater than 2 the **SPECIFIC POWER** key is used. **^**

Enter the main number

Press the **SPECIFIC POWER** key

Enter the numerical power

#1 $3.5^3 =$ **42.875**

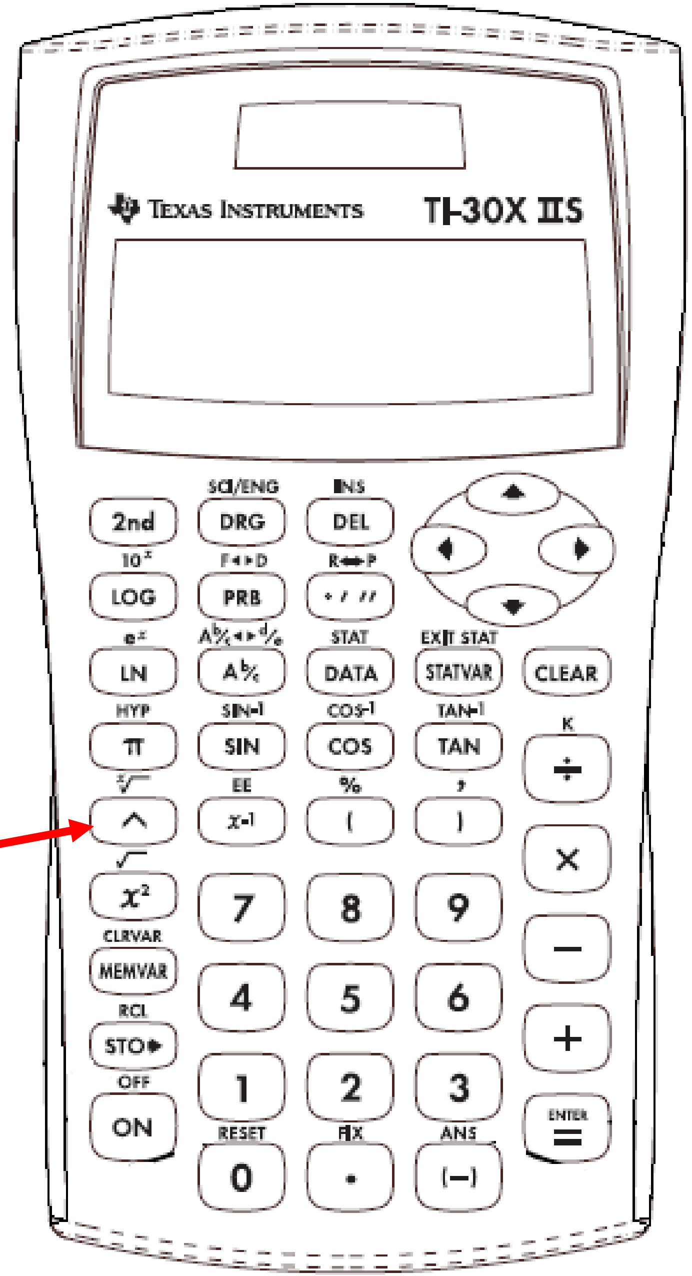
#2 $364^4 =$ **1.7555x10**

#3 $17.23^5 =$ **1,518,540.528**

#4 $12.25^5 =$ **275,854.74**

#5 $1.86^3 =$ **6.43**

^



Courtesy of Texas Instruments

Exponentiation – Fractional Exponents

Raising numbers to fractional powers is done by:

Enter the main number

Press the **SPECIFIC POWER** key

Enter the exponent

#1 $24^{1.08} =$ **30.95**

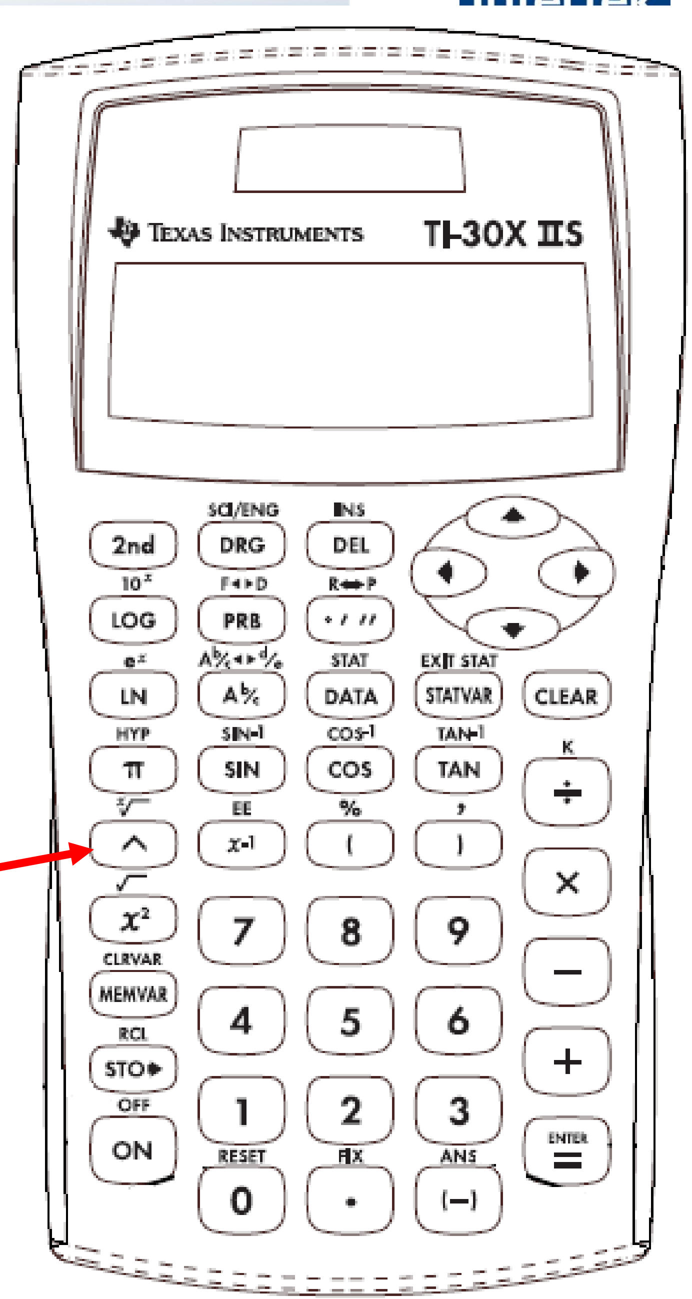
#2 $17.5^{.125} =$ **1.43**

#3 $101.75^{.325} =$ **4.49**

#4 $420^{1.885} =$ **88,069.37**

#5 $.7856^{3.887} =$ **.39**

^



Courtesy of Texas Instruments

Rig Math

Obtaining The Square Root

To get the **SQUARE ROOT** of a number:

Press the **2nd** key

Press the **SQUARE ROOT** key – a set of parentheses will open

Enter the number and then press the **CLOSE PARENTHESE** key

#1 $\sqrt{(78.56)} =$ **8.86**

#2 $\sqrt{(8.755)} =$ **2.96**

#3 $\sqrt{(8965437)} =$ **2,994.23**

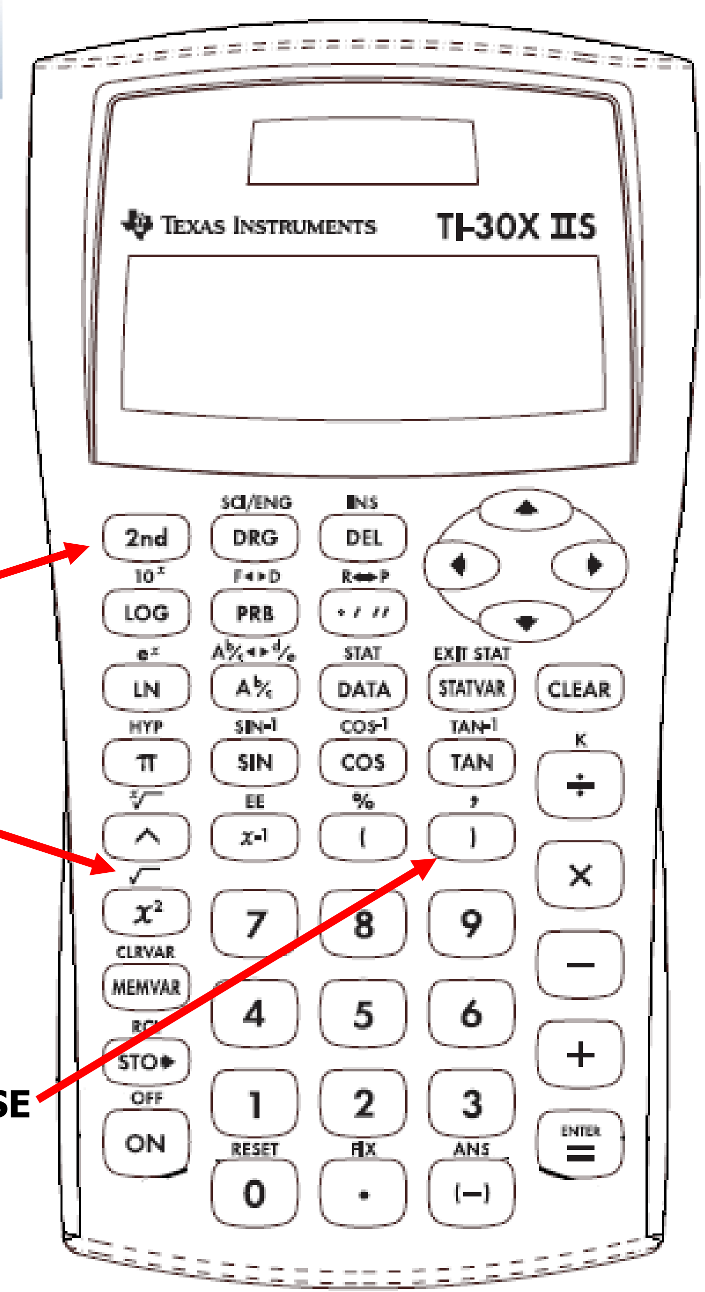
#4 $\sqrt{(12.7843)} =$ **3.58**

#5 $\sqrt{(10829564)} =$ **3,290.83**

2nd Key

SQUARE ROOT

CLOSE PARENTHESE



Courtesy of Texas Instruments

Single and Multi-Level Parentheses

Parentheses surround and resolve individual operations such as addition, multiplication, subtraction and division. They work in "pairs." Using the parentheses eliminates a great deal of recording the results of individual operations.

The left hand parentheses opens the operation* ( ) *The right hand parentheses closes the operation

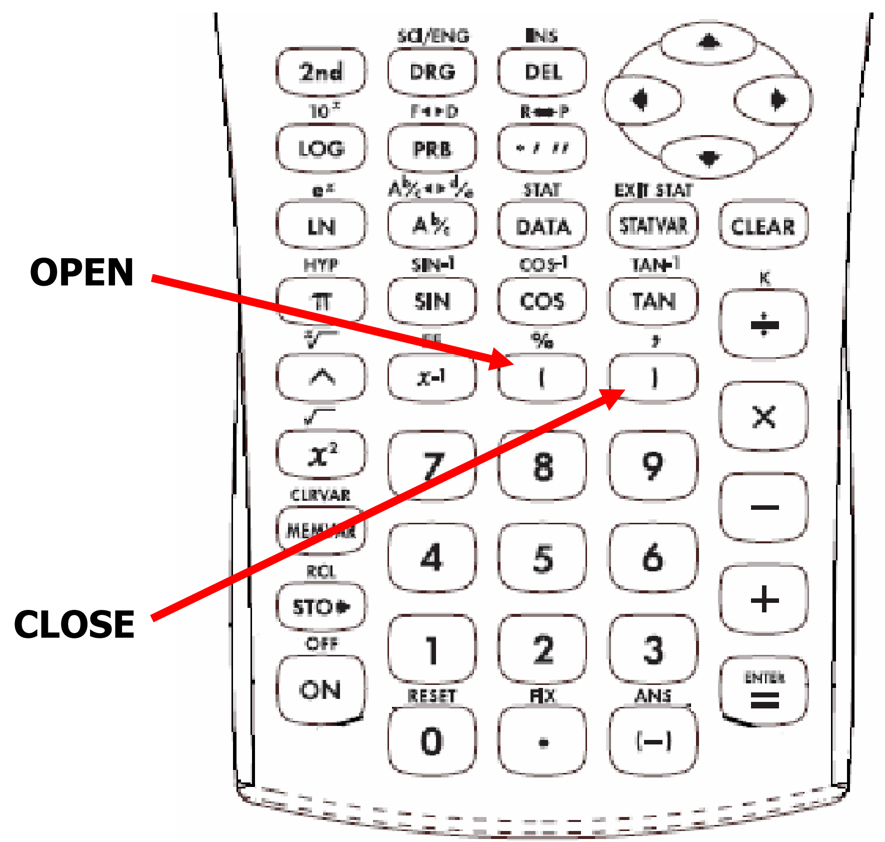
Examples

#1 $(32.5 + 11) \times 10 =$ **435**

#2 $\left(\dfrac{14.7}{11.9}\right) \times 800 =$ **988.24**

#3 $\dfrac{(65.4 - 17.2)}{65.4} =$ **.74**

#4 $\dfrac{(5^2 - 4.276)}{1029} =$ **.02**



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Single and Multi-Level Parentheses

Examples

#1 $$\left(\frac{\left(8.5^2 - 5^2\right)}{1029}\right) \times 5000 = \underline{\textbf{229.59}}$$

#2 $$\left(\frac{\left(4.5 \times 42\right)}{\left(2.45 \times \left(8.5^2 - 5^2\right)\right)}\right) = \underline{\textbf{1.63}}$$

#3 $$\left(\frac{\left(3.4 \times 16 \times 4800\right)}{\left(1000 \times \left(8.5 - 5\right)^2\right)}\right) + \left(\frac{\left(14 \times 4800\right)}{\left(200 \times \left(8.5 - 5\right)\right)}\right) = \underline{\textbf{117.32}}$$

#4 $$2.45 \times \sqrt{\left(\frac{1325 \times .78}{312}\right)} \times 3.78 = \underline{\textbf{16.86}}$$

Accurate Drill Collar Weight

Non-Spiraled Collars

The weight on pounds per foot and total weight of a drill collar can be calculated by knowing the OD, the ID, and the length of the drill collar. The following two formulas are used to determine this.

$$\left(\frac{\left(OD^2 - ID^2\right)}{1029.4}\right) \times 2748 = Weight_{\#/Ft}$$

$$Weight_{\#/ft} \times Length_{Feet}$$

Use the two formulas above and the information given below to calculate the weight in pounds per foot and the total weight for these drill collars.

Examples:

Drill Collar Dimensions	Weight #/ft	Total Weight
9″ OD, 3 ¼″ ID, 90′	188.03	16,923
6 ¾″ OD, 2 ½″ ID, 180′	104.95	18,890
7 ¾″ OD, 3″ ID, 270′	136.31	36,804
5 1/8″ OD, 1 7/8″ ID, 360′	60.73	21,863

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Spiraled Collars

When drill collars are machined with a spiral OD, some of the weight is lost; actually about 4% of the total weight is machined off. So the collar weighs approximately 96% of its original weight. The following formula can be used to estimate the weight of a spiraled drill collar in pounds per foot. Once the weight per foot is calculated and the length is known, the total weight of the drill collar can be determined. Calculate the "per foot" weight and the total weight for the following drill collars.

$$\left(\frac{(OD^2 - ID^2)}{1029.4}\right) \times 2748 \times .96 = Weight_{\#/Ft}$$

Examples:

Drill Collar Dimensions	Weight #/ft	Total Weight
9" OD, 3 ¼" ID, 90'	180.51	16,246
6 ¾" OD, 2 ½" ID, 180'	100.75	18,135
7 ¾" OD, 3" ID, 270'	130.86	35,332
5 1/8" OD, 1 7/8" ID, 360'	58.30	20,989

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Buoyancy

Buoyancy is a property of a liquid to support a portion or all of the weight of an object immersed in the liquid. The more dense the liquid is, the more buoyant it is. For example, it's easier to swim in salt water than fresh water due to the higher density of salt water. An object in salt water weighs less than it does in fresh water. The following formula is used to determine the buoyant effect, or better known as the ***Buoyancy Factor*** for steel immersed in drilling mud.

$$\frac{(65.4 - Mud\ Weight_{ppg})}{65.4} = Buoyancy\ \ Factor$$

Example:

Use the formula above to calculate the buoyancy factors for the following mud weights.

8.8 ppg	**.8654** BF
9.2 ppg	**.8593** BF
13.8 ppg	**.7890** BF
17.9 ppg	**.7263** BF

How Buoyancy Affects the Weight of the Drill String

$$Pipe\ Wt._{\#/\ ft} \times \left(\frac{(65.4 - MW_{ppg})}{65.4}\right) \times Length_{Feet}$$

This formula will give you the weight of a length of pipe immersed in a certain mud weight.

Example:

Use the following information and the buoyancy factor formula to calculate the immersed weight of these drill strings.

#1	Drill Pipe	5878′, 21.92#/ft	108,751 #
	Heavy Weight	1300′, 44.6#/ft	48,937 #
	Drill Collars	120′, 108.76#/ft	11,016 #
	Mud Weight	10.2 ppg	

Drill String Weight = 168,704 lbs

The formula above is used to calculate the weight of each section of the drill string and then the section weights are added to arrive at the entire weight of the drill string.

#2	Drill Pipe	15920′, 26.74#/ft	320,903 #
	Heavy Weight	1300′, 49.0#/ft	48,019 #
	Drill Collars	360′, 97.64#/ft	26,497 #
	Mud Weight	16.1 ppg	

Drill String Weight = 395,419 lbs

#3	Upper Drill Pipe	9800′, 21.92#/ft	177,371	#
	Lower Drill Pipe	2816′, 19#/ft	44,178	#
	Heavy Weight	1708′, 49.7#/ft	70,091	#
	Drill Collars	120′, 118#/ft	11,692	#
	Mud Weight	11.4 ppg		

Drill String Weight = 303,332 lbs

#4	Upper Drill Pipe	3920′, 29.64#/ft	85,099	#
	Lower Drill Pipe	11892′ 23 #/ft	200,327	#
	Heavy Weight	1300′, 57.4#/ft	54,653	#
	Upper Drill Collars	360′, 92.84#/ft	24,479	#
	Lower Drill Collars	90′, 132.4 #/ft	8,727	#
	Mud Weight	17.5 ppg		

Drill String Weight = 373,285 lbs

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How Angle & Buoyancy Affects Drill String Component Weight

Not only does the mud weight affect the weight of the drill string but the hole angle does also. The greater the hole angle, the less effective weight the drill string has. The following formula can be used to determine the weight of pipe immersed in a mud and in a deviated hole.

$$Pipe\ Weight_{\#/ft} \times BF \times COS\angle \times Length$$

Example:

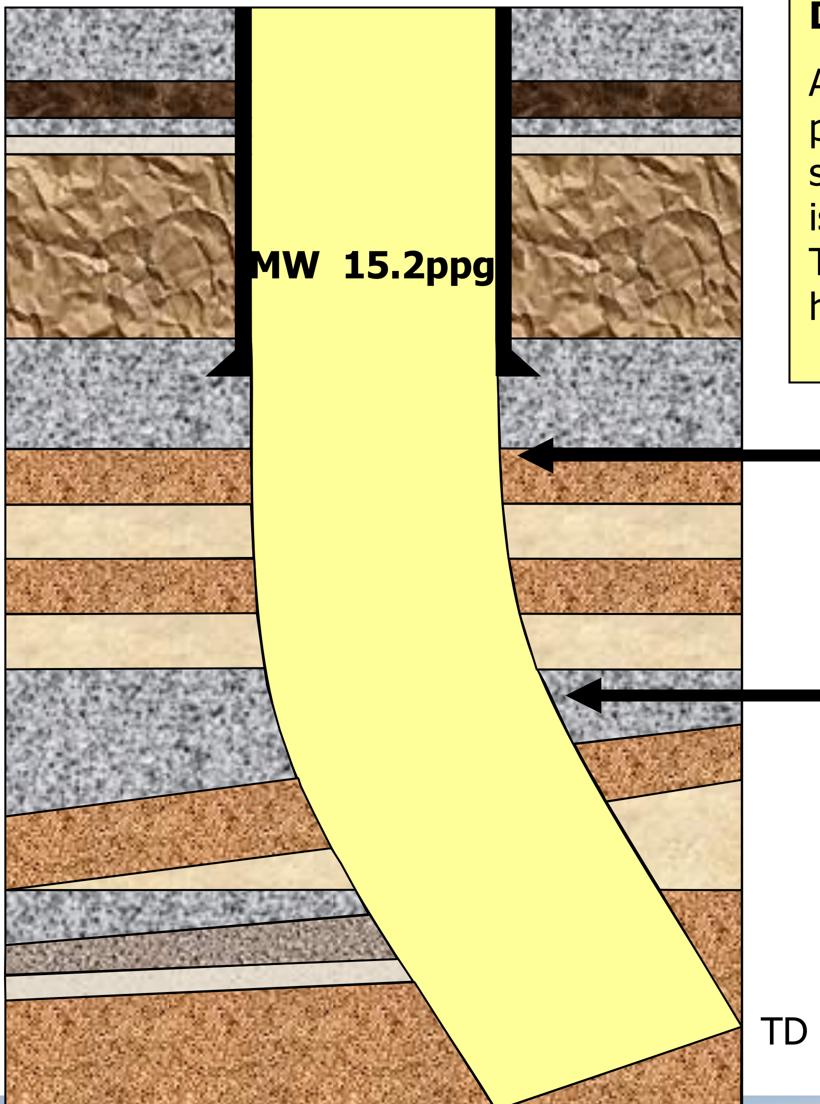
#1	BHA:	360' Drill Collars:	101.25#/ft	22,662 #
		810' Heavy Weight:	51#/ft	25,684 #
		Mud Weight:	13.8 ppg	.7890 BF
		Hole Angle:	38°	

BHA Weight = 48,346 lbs

#2	BHA:	90' Drill Collars:	98.25#/ft	2,020 #
		1250' Heavy Weight:	49.7#/ft	14,190 #
		Mud Weight:	16.0 ppg	.7554 BF
		Hole Angle:	72.4°	

BHA Weight = 16,210 lbs

Estimating Total Drill String Weight In a Deviated Wellbore



DP 15252′, 21.92#/ft

HW 1029′, 54#/ft

DC 270′, 102.78#/ft

As you can see by the lengths given above, part of the drill pipe section would be in the vertical section, part in the build section where angle is being increased, and a third section is in the tangent section where the hole angle is constant. The combination of hole angle and the buoyancy factor will have a direct impact of the actual weight of the string.

KOP: kick-off point

EOB: end of the build

A practical way of calculating the section of the drill string in the build section is to calculate an average angle for that section. Then apply the cosine of the average angle and the buoyancy factor to arrive at an estimated weight. The following formula can be used to accomplish this.

$$DP\ Weight_{\#/\ ft} \times BF \times COS\left(\frac{Maximum\ \angle}{2}\right)$$

To calculate the weight for the remaining portion of the drill pipe as well as the heavy weight and drill collar sections, use the previously introduced formulas. So, the formulas to be used are as follows:

For the vertical section $$Pipe\ Weight_{\#/\ ft} \times BF \times Length_{Feet}$$

For the build section $$Pipe\ Weight_{\#/\ ft} \times BF \times COS\left(\frac{Maximum\ \angle}{2}\right) \times Length$$

For the tangent section $$Pipe\ Weight_{\#/\ ft} \times BF \times COS\angle \times Length$$

Based on this information calculate the weight of the entire drill string from the previous page.

Total drill string weight = ______________ lbs

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Tensile Strength

The tensile strength of drill pipe, heavy weight and collars is based on the cross sectional area and the grade of steel used in making the pipe. We'll use drill pipe as an example. Drill pipe is manufactured in the following grades:

E-75	E – 75,000 psi
X-95	X – 95,000 psi
G-105	G – 105,000 psi
S-135	S – 135,000 psi
V-155	V – 155,000 psi

The letter designates the alloy the pipe is made of and the number represents the minimum yield in thousands of pounds per square inch of steel.

In order to estimate the tensile strength you must know the pipe grade and the cross sectional area of the steel in square inches. The following formula is used to determine the tensile strength:

$$\left(OD^2_{Pipe} - ID^2_{Pipe}\right) \times .7854 \times Minimum\ Yield$$

Example:

Drill Pipe OD	5"
Drill Pipe ID	4.276"
Drill Pipe Grade	G (105,000 psi)

$$\left(5^2_{Pipe} - 4.276^2_{Pipe}\right) \times .7854 \times 105000_{psi} = 553833.8 \approx 553834\#$$

Calculate the tensile strengths for the following grades of drill pipe:

#1 5″ OD

4.276″ ID

Grade X-95

Tensile = **501,088** #

#2 4 ½″ OD

3.826″ ID

Grade S-135

Tensile = **595,005** #

#3 3 ½″ OD

2.763″ ID

Grade V-155

Tensile = **561,917** #

Maximum Overpull

Maximum overpull is the difference between a present string weight and the estimated tensile strength of the top joint of drill pipe. There is usually a safety factor used when the calculation is made, but for this example no safety factor will be used.

Calculate the estimated tensile strength of the drill pipe and then calculate the total weight of the drill string.

Tensile Strength

$$\left(OD^2_{Pipe} - ID^2_{Pipe}\right) \times .7854 \times Minimum\ Yield$$

Maximum Overpull

$$Tensile\ Strength - \left(String\ Weight + Drag\right)$$

String Wt + Drag = Total Pipe Load

Example: a drill string consists of the following components:

Drill Pipe:	11428' 5" OD, 4.276" ID, Grade G, 23.07#/ft
Heavy Weight:	1320' 5" OD, 3" ID, 49.7#/ft
Drill Collars	120' 7" OD, 3" ID, 106.82#/ft
Mud Weight:	14.3 ppg
KOP:	9860'
EOB:	11428'
Hole Angle:	37 degrees
Last Recorded Drag:	62000#

Note: the entire BHA (heavy weight and drill collars) is beyond the EOB

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Use these formulas for your calculations

Drill Pipe Tensile

$$\left(OD_{Pipe}^2 - ID_{Pipe}^2\right) \times .7854 \times Minimum\ Yield$$

Buoyancy Factor

$$\frac{\left(65.4 - Mud\ Weight_{ppg}\right)}{65.4} = Buoyancy\ Factor$$

String Weight

For the vertical section $$Pipe\ Weight_{\#/\ ft} \times BF \times Length_{Feet}$$

For the build section $$Pipe\ Weight_{\#/\ ft} \times BF \times COS\left(\frac{Maximum\ \angle}{2}\right) \times Length$$

For the tangent section $$Pipe\ Weight_{\#/\ ft} \times BF \times COS\angle \times Length$$

Maximum Overpull

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Use this page for your calculations

Drill Pipe Tensile = 553,834 #

Buoyancy Factor = .7813

String Weight

Vertical Section = 205,985 #

Build Section = 26,802 #

Tangent Section = 20,729 #

Total String Weight = 253,516 #

Total Pipe Load = 315,516 #

Maximum Overpull = 238,318 #

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Hydrostatics

Simply defined, hydrostatic pressure is the pressure exerted by a static column of fluid due to two things:

The density of the fluid

The vertical length of the column of fluid

We generally think of hydrostatic pressure in terms of a column of mud, but gas, although having slight density, can also exert a hydrostatic pressure.

To estimate the ***hydrostatic pressure*** of a column of liquid, the following formula is used:

$$.052 \times Fluid\ \ Weight_{\ ppg} \times Length_{Vertical}$$

You'll notice that the density of the fluid in the formula is in pounds per gallon. Another way of looking at density is in terms of the pressure exerted by a one foot column of that fluid. This is commonly referred to as the ***fluid gradient***. To determine the gradient of a fluid whose density is measured in pounds per gallon perform the following calculation:

$$.052 \times Fluid\ \ Weight_{\ ppg}$$

Some fluids encountered in drilling or completing a well are commonly measured in their gradients such as gas and produced water. If the gradient of a fluid is known simply ***multiply the gradient times the vertical length of the column*** to determine the hydrostatic pressure.

Hydrostatic Pressure Calculations

Calculate the hydrostatic pressure for the following columns of weighted fluids:

Mud Weight$_{PPG}$	Vertical Length ft	Hydrostatic Pressure
11.4	12398	7350 psi
17.4	21287	19,260 psi
9.2	8785	4203 psi
12.4	11280	7273 psi

Calculate the hydrostatic pressure for the following columns of gas and produced water.

Gas Gradient	Vertical Length ft	Hydrostatic Pressure
.135 psi/ft	1345	182 psi
.1 psi/ft	2000	200 psi
.115 psi/ft	1500	173 psi
.12 psi/ft	15000	1800 psi

Water Gradient	Vertical Length ft	Hydrostatic Pressure
.451 psi/ft	7800	3518 psi
.433 psi/ft	200	87 psi
.465 psi/ft	9000	4185 psi
.487 psi/ft	11000	5357 psi

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Hydrostatic Pressure Calculations for Gas and Produced Water

Both gas and produced water are measured in their gradients, or pressure per foot. To calculate the hydrostatic pressure of either, use the following formula.

$$Gradient_{PSI/FT} \times Vertical\ \ Length_{Feet}$$

Hydrostatic Pressure For a Column of Gas

#1 Gas Gradient .12 psi/ft
Length 687 feet
Hydrostatic = **82** psi

#2 Gas Gradient .134 psi/ft
Length 1129 feet
Hydrostatic = **151** psi

#3 Gas Gradient .1 psi/ft
Length 1267 feet
Hydrostatic = **127** psi

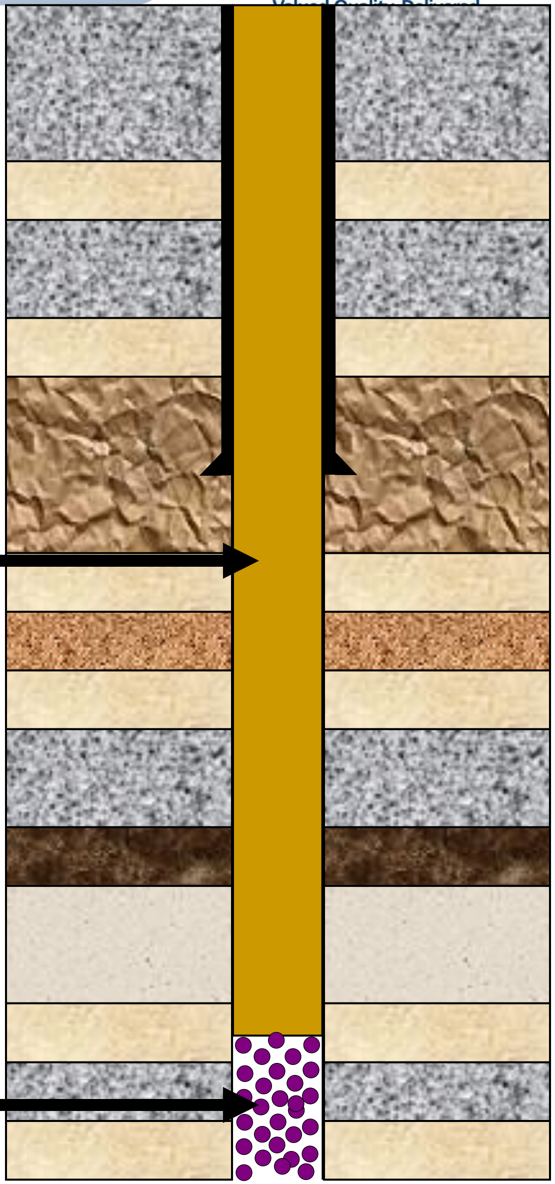
Hydrostatic Pressure For a Column of Water

#1 Water Gradient .433 psi/ft
Length 2375 feet
Hydrostatic = **1028** psi

#2 Gas Gradient .465 psi/ft
Length 400 feet
Hydrostatic = **186** psi

#3 Gas Gradient .457 psi/ft
Length 4877 feet
Hydrostatic = **2229** psi

Based on the information at right, calculate the total hydrostatic pressure in this wellbore.



Mud Hydrostatic Pressure = **9551** psi

Gas Hydrostatic Pressure = **172** psi

Total Wellbore Hydrostatic Pressure = **9723** psi

Rig Math

In many cases, wells are drilled overbalanced. The term ***overbalanced*** means that the hydrostatic pressure of the mud exceeds the pressure within the open hole formations. To obtain an estimate of the overbalance, calculate the difference between the mud hydrostatic pressure and the estimated formation pressure ,at a particular depth.

Based on this and the information below, calculate the overbalance for each listed formation pressure at its depth compared to the mud weight.

$$Formation\ PSI = \left(.052 \times MW \times Length_{Vertical}\right)$$

Mud Hydrostatic = **4423** psi

Mud Weight of 12.4 ppg

6860′, Formation Pressure of 3120 psi

Overbalance = **1303** psi

Mud Hydrostatic = **5971** psi

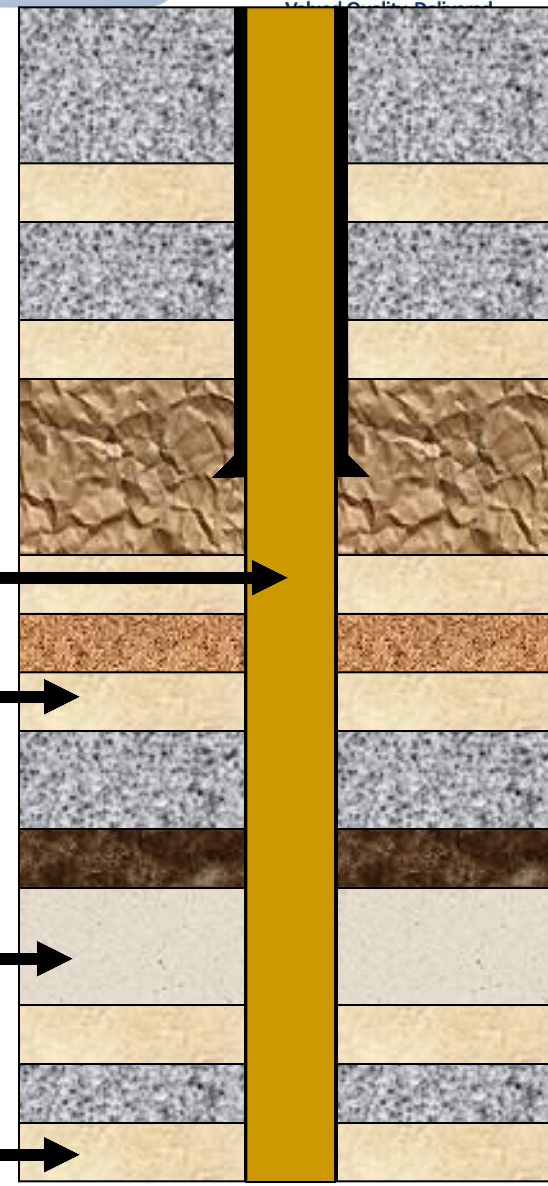
9261′, Formation Pressure of 4550 psi

Overbalance = **1421** psi

Mud Hydrostatic = **7272** psi

11278′ with a Formation Pressure of 7155 psi

Overbalance = **117** psi



Rig Math

Wellbore Volume Calculations

It's essential, for many reasons, that the rig crew be able to calculate and keep current with the volume of mud in the hole. The following two formulas are used to acquire and estimate of the hole volume.

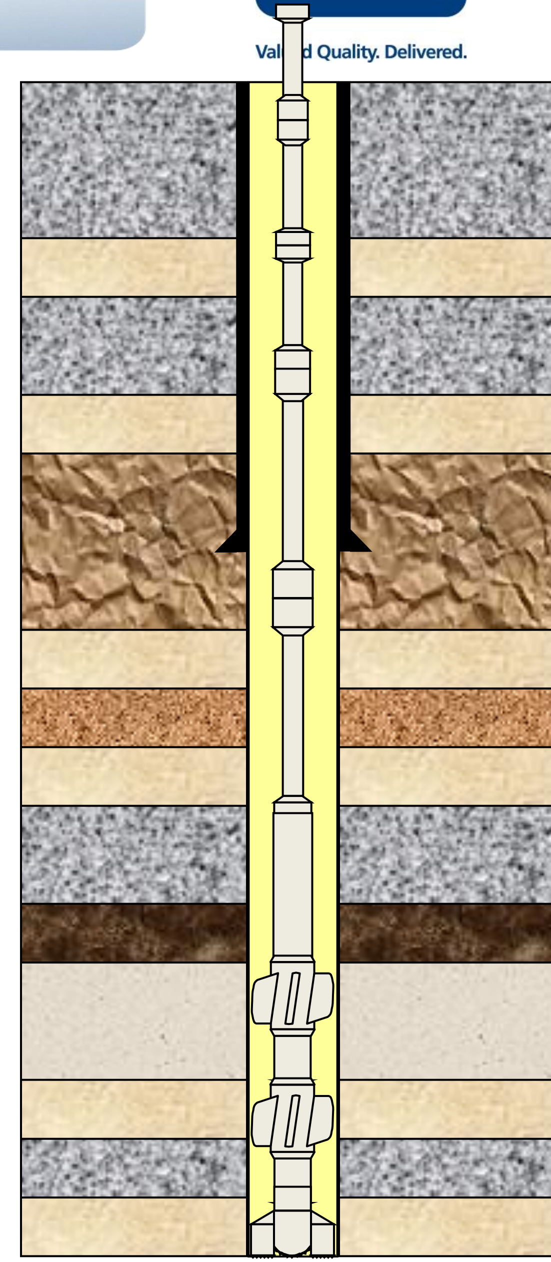
To calculate the volume of various components of the drill string, or to calculate the volume of open casing or the open hole, the following is used:

$$\left(\frac{ID_{Pipe}^{2}}{1029.4}\right) = Capacity\ \ Factor$$

$$\left(\frac{ID_{Pipe}^{2}}{1029.4}\right) \times Length = Volume\ of\ \ Interest$$

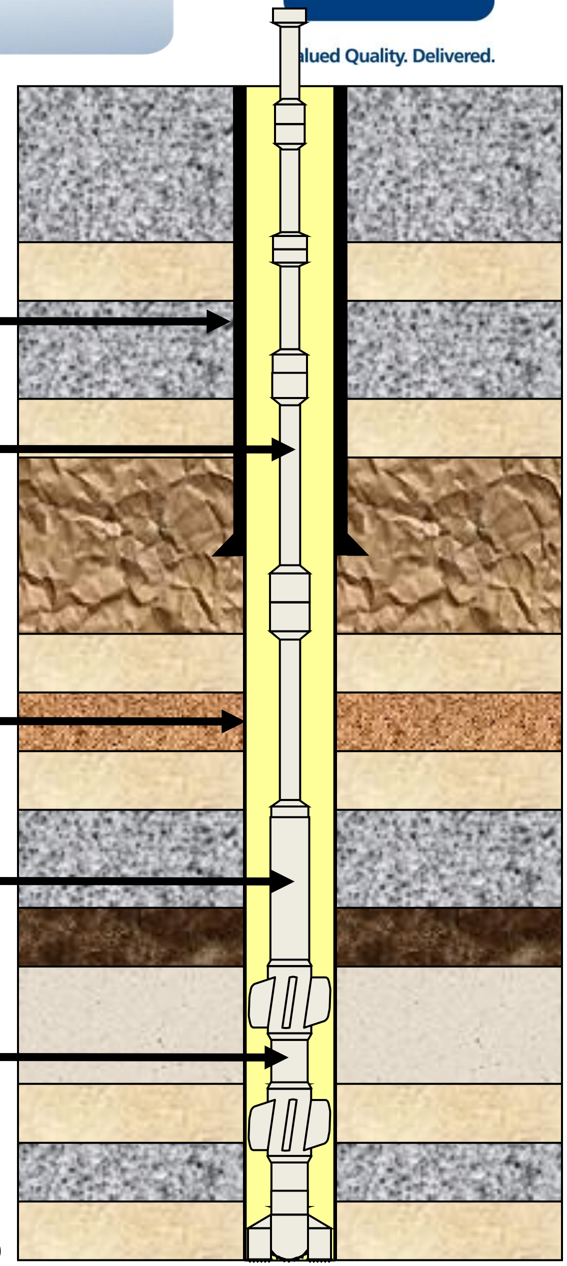
To calculate the volume in a particular annular section the formula below is used.

$$\left(\frac{\left(ID_{Annulus}^{2} - OD_{Pipe}^{2}\right)}{1029.4}\right) \times Length = \ Annulas\ Volume$$



Rig Math

Based on the information given and the two formulas on the preceding page, calculate the wellbore volume.



Drill String Volume

Drill Pipe Volume = 195.38 bbl

Heavy Weight Volume = 5.68 bbl

Drill Collar Volume = 1.77 bbl

Annular Volume

DC in Open Hole Volume = 9.33 bbl

HW in Open Hole Volume = 29.84 bbl

DP in Open Hole Volume = 257.04 bbl

DP in Cased Hole Volume = 264.18 bbl

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Strokes To Displace A Known Volume

In order to determine how many pump strokes it will take to pump a particular volume one must know the volume to be pumped and also the output of the pump. In the case of a triplex pump, the output can be calculated using the following formula:

Triplex Pump Output Formula

$$ID^2_{Liner} \times Stroke\ Length_{Inches} \times .000243 \times Volumetric\ \ Efficiency$$

It's fairly easy to find out the liner size and stroke length, but the volumetric efficiency can and should be determined with a simple field test.

First, calculate the pump output as though the pump operates at 100% efficiency. This is done by using the above formula and omitting the volumetric efficiency. For this example we'll use:

Liner Size	6 ¾″
Stroke Length	12 inches

$$ID^2_{Liner} \times Stroke\ Length_{Inches} \times .000243 = BBL / STK$$

$$6.75^2_{Liner} \times 12_{Inches} \times .000243 = .1329_{BBL / STK}$$

Next, calculate the strokes required to pump a known volume. This is done by using this formula:

$$\frac{Volume_{BBL}}{Pump\ Output_{BBL/STKS}}$$

Continuing with this example, we'll use a volume of 10 bbl. The pump should be lined up to a calibrated tank such as a trip tank so that the pumped volume can be accurately measured. The number of strokes required to pump 10 bbl is calculated:

$$\frac{10_{BBL}}{.1329_{BBL/STKS}} = 75.2 \approx 75_{Strokes}$$

In this case, the driller lined up the pump to a trip tank and pumped 10 bbl. He noticed that it took 79 strokes to pump 10 bbl. Obviously the pump is not 100% efficient. The efficiency can then be determined by calculating a ratio between the calculated strokes and the observed strokes.

$$\frac{75\ calculated\ \ strokes}{81\ observed\ \ strokes} = .9259$$

.9259 is the same as 92.59% efficient. The decimal figure of .9259 is used in determining the pump output.

So the actual pump output is calculated using the following:

$$ID^2_{Liner} \times Stroke\ Length_{Inches} \times .000243 \times Volumetric\ \ Efficiency$$

$$6.75^2_{Liner} \times 12_{Inches} \times .000243 \times .9259 = .1230_{BBL/STK}$$

Once the actual pump output is known, the displacement strokes can be calculated and if the pump rate is known, then the time required to displace that volume can also be calculated.

For example, the wellbore volume has been calculated to be 1200 bbl and it is to be totally displaced at a rate of 75 spm. Using this information and the calculated pump output above, we can perform both calculations.

$$\frac{1200_{BBL}}{.1230_{BBL/STKS}} = 9756_{Strokes}$$

To determine the approximate circulating time to displace this volume:

$$\frac{9756_{Strokes}}{75_{SPM}} = 130_{\text{min}}$$

Rig Math

Calculate this wellbore volume and determine the total pump strokes required to pump the entire volume along with the approximate time to get this done.

Casing ID 8.755″ shoe set @ 7256′

13542′ 5″ OD x 4.276″ ID

Pump: 5 ¾″ Liner, 10″ stroke

92% Efficiency

Pump Rate 80 spm

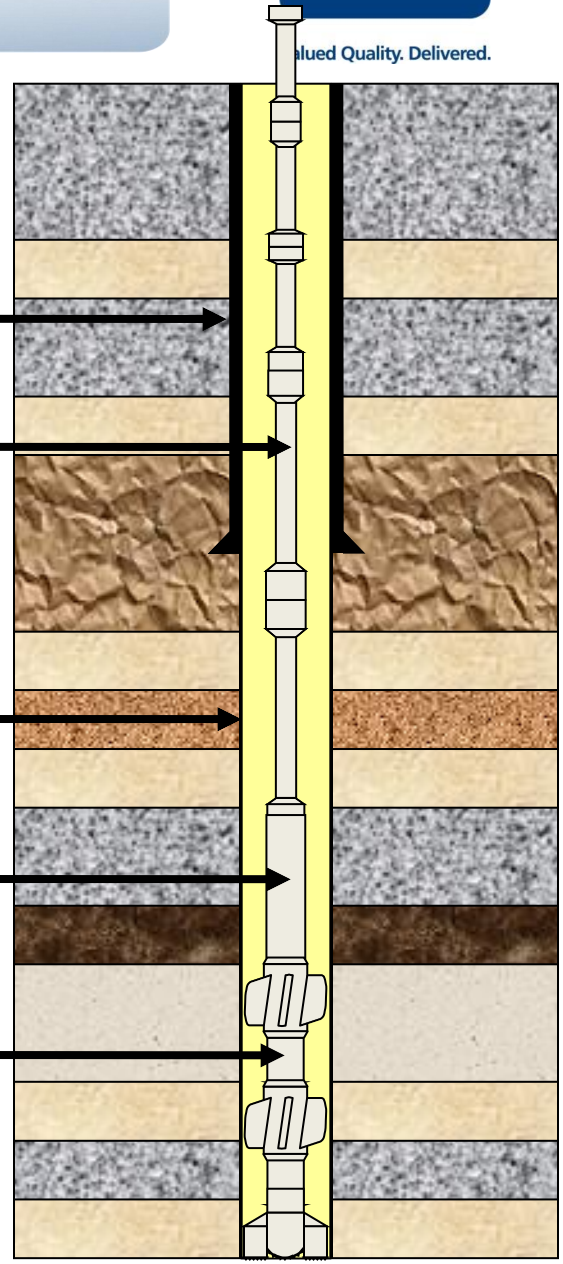
Use the following page to record your calculations.

8 ½″ Open Hole

810′ 5″ OD x 3″ ID

180′ of 7″ x 3″

14532′ TD



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Drill Pipe Volume = 240.53 bbl

Heavy Weight Volume = 7.08 bbl

Drill Collar Volume = 1.57 bbl

Drill String Volume = 249.18 bbl

Drill Collars in Open Hole Volume = 4.07 bbl

Heavy Weight in Open Hole Volume = 37.18 bbl

Drill Pipe in Open Hole Volume = 288.53 bbl

Drill Pipe in Cased Hole Volume = 364.07 bbl

Annular Volume = 693.85 bbl

Pump Output = .0739 bbl/stk

Strokes to Displace Drill String = 3372 strokes

Approximate Circulating Time = 160 minutes

Determining Required SPM For A Desired BPM Flowrate

Based on the pump output and a desired flowrate in BPM you can calculate the required SPM rate to run the pump. The formula below will accomplish this.

$$\frac{Desired\ \ Flowrate_{BPM}}{Pump\ \ Output_{BBL\ /\ STK}}$$

Example: We want to pump at a flowrate of 3 ½ BPM using a triplex pump having a liner of 6 ½”, a stroke length of 10”, and an efficiency of 90%.

First, calculate the pump output.

$$6.5^2_{Liner} \times 10_{Inches} \times .000243 \times .90 = .0924_{BBL\ /\ STK}$$

Calculate the required SPM that will result in a flowrate of 3 ½ BPM.

$$\frac{3.5_{BPM}}{.0924_{BBL\ /\ STK}} = 37.8 \approx 38_{SPM}$$

From the information provided below, calculate the required SPM rates to run the pump to achieve the desired flowrates in BPM.

#1	Pump:	8” liner, 12” stroke, 88% efficiency
	Desired Flowrate:	4 bpm
	Required Pump Rate =	25 spm
#2	Pump:	6” liner, 10” stroke, 92% efficiency
	Desired Flowrate:	5 bpm
	Required Pump Rate:	63 spm
#3	Pump:	3 ½” liner, 8” stroke, 80% eficiency
	Desired Flowrate:	2 ¼ BPM
	Required Pump Rate:	118 spm
#4	Pump:	4 ¾” liner, 6 ½” stroke, 88% efficiency
	Desired Flowrate:	3 bpm
	Required Pump Rate:	96 spm

Determining The Flowrate Based On Pump Rate in SPM

If you need to know the flowrate in BPM when pumping at a certain SPM rate, this formula below can be used.

$$Pump\ Output_{BBL/STK} \times SPM$$

Determine the pump output using the formula previously presented, then multiply the pump rate in SPM by the pump output.

Example: A triplex pump having a liner of 8”, a stroke length of 12”, and an efficiency of 92% is being run at a rate of 52 spm. What is the flowrate in BPM?

Calculate the pump output

$$8^2_{Liner} \times 12_{Inches} \times .000243 \times .92 = .1717_{BBL/STK}$$

Calculate the flowrate in BPM

$$.1717_{BBL/STK} \times 52_{SPM} = 8.9_{BPM}$$

Use the information below to determine the flowrates in BPM based on the pump outputs and the pump rates in SPM.

#1 Pump: 8" liner, 12" stroke, 88% efficiency

Pump Rate spm: 32 spm

Flowrate = 5.26 bpm

#2 Pump: 6" liner, 10" stroke, 92% efficiency

Pump Rate: 40 spm

Flowrate = 3.22 bpm

#3 Pump: 3 ½" liner, 8" stroke, 80% eficiency

Pump Rate: 70 spm

Flowrate = 1.33 bpm

#4 Pump: 4 ¾" liner, 6 ½" stroke, 88% efficiency

Pump Rate: 65 spm

Flowrate = 2.04 bpm

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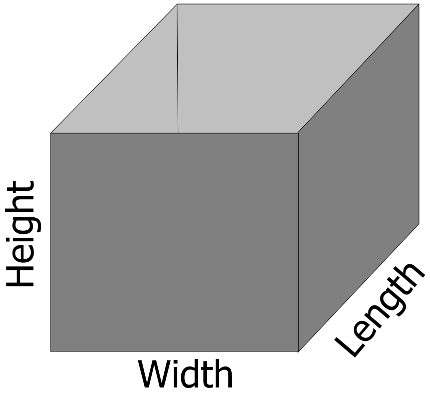
Estimating Mud Tank Volume

To determine the volume of a rectangular steel pit, the dimensions of the pit must be know. Namely the ***height*, *length*** and ***width*.**

Once these dimensions are known the following formula can be used to calculate the volume of the pit in bbl.

$$Height_{Feet} \times Length_{Feet} \times Width_{Feet} \times .1781 = Barrels$$



Let's suppose this pit measures: 6 feet in height, 8 feet in width, and 15 feet in length. The volume can be calculated as such:

$$6_{Feet} \times 15_{Feet} \times 8_{Feet} \times .1781 = 128_{BBL}$$

Calculate the volume of these tanks:

#1	Height	8.5 feet
	Length	24 feet
	Width	10 feet
	Volume = 363.32 bbls	

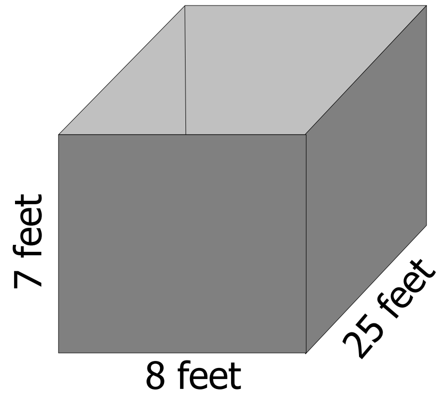
#2	Height	12 feet
	Length	30 feet
	Width	12 feet
	Volume = 769.39 bbls	

#3	Height	7 feet
	Length	12 feet
	Width	5 feet
	Volume = 74.8 bbls	

It may be beneficial to know how many BBLS occupy each inch of height in a tank, or how many inches equate to a certain number of BBLS. This can be accomplished using the following:

Tank Volume BBL/Inch:

$$\frac{Tank\ Volume_{BBL}}{\left(Height_{Feet} \times 12\right)}$$



Tank Volume Inches/BBL:

$$\frac{\left(Height_{Feet} \times 12\right)}{Tank\ Volume_{BBL}}$$

Calculate the volume of this tank and determine its measurement in BBL/Inch and Inches/BBL.

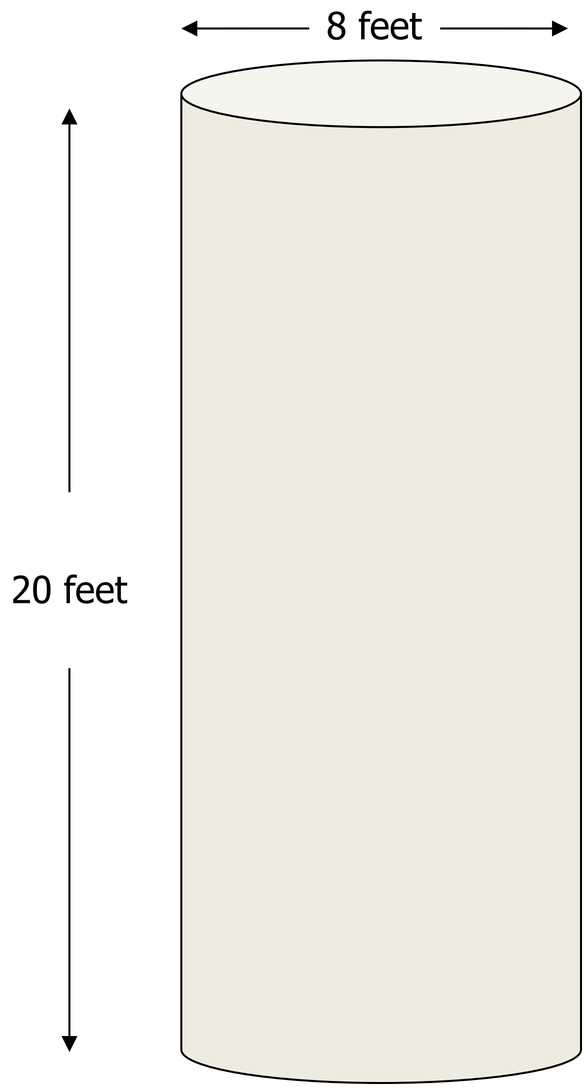
BBL/Inch = **2.97**

Inches/BBL = **0.37**

The volume of a vertically-oriented cylindrical tank, commonly called a frac tank, can be calculated by using the following formula.

$$\left(\frac{(Diameter_{Feet} \times 12)^2}{1029.4}\right) \times Height_{Feet}$$

$$\left(\frac{(8_{Feet} \times 12)^2}{1029.4}\right) \times 20_{Feet} = 179_{BBL}$$

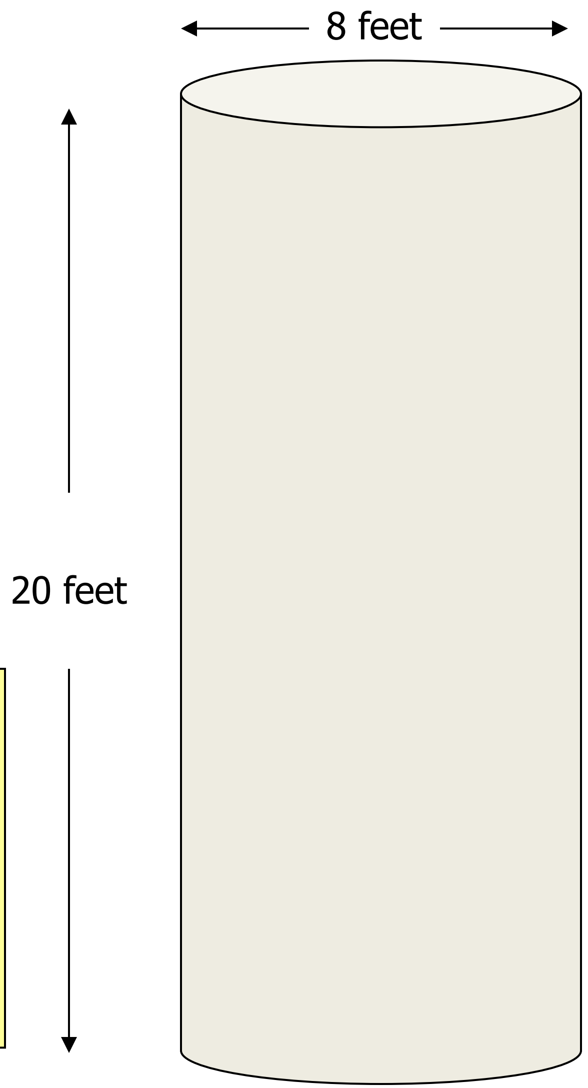


Calculate the volume of these tanks:

#1 Height 16 feet
Diameter 6.5 feet
Volume = **94.56** BBL

#2 Height 8 feet
Diameter 4 feet
Volume = **17.91** BBL

Similarly to the rectangular tank, the volume in BBL/Inch and Inches/BBL can also be calculated for a cylindrical tank.



Tank Volume BBL/Inch:

$$\frac{Tank\ Volume_{BBL}}{\left(Height_{Feet}\ \times 12\right)}$$

Tank Volume Inches/BBL:

$$\frac{\left(Height_{Feet}\ \times 12\right)}{Tank\ Volume_{BBL}}$$

Calculate the volume of this tank and determine its measurement in BBL/Inch and Inches/BBL.

BBL/Inch = **0.75**

Inches/BBL = **1.34**